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A soil depth prediction scheme for geomorphologic and hydrologic distributed modeling

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In mountainous, soil covered terrains, the depth of the rupture surface in shallow, rainfall-triggered landslides is controlled by rainfall characteristics, namely intensity and duration, slope topographic attributes and soil permeability. If these factors are well characterized at a basin scale, the main constraint on the depth of failure becomes soil thickness, intended here as depth to bedrock. Soil thickness is a key parameter in many surface and subsurface processes such as landsliding, rainfall infiltration, erosion, landscape evolution, etc. and is a fundamental component in the modeling of these processes. However, notwithstanding its significance, it is still one of the least understood and difficult to measure physical variables of the entire hillslope system, especially when considered at catchment scale. In areas dominated by active geomorphologic processes such as soil erosion and shallow landsliding, this uncertainty severely constrains the reliability of numerical models. Within a river basin soil thickness z can vary as a function of many different and often interrelated parameters among which we can count vegetation cover, lithology, climate, gradient, hillslope curvature, upslope contributing area and land use. For the application of numerical codes regarding shallow landslide stability, such as the commonly used infinite slope stability model, soil depth is often assigned a constant value for the entire basin, or a very simple model is used. Some of the most widespread are, for example, the direct correlation of soil thickness with elevation, or with slope gradient. If some punctual measurements of soil thickness have been carried out in the field, the extension to basin scale usually involves a simple linear relationship with gradient, where z is considered inversely proportional to slope gradient at a point. We present here an alternative methodology which links soil thickness to gradient, horizontal and vertical slope curvature and relative position within the hillslope profile. This last parameter is fundamental: points having equal gradient and curvature can have very different soil thicknesses due to their different position on the hillslope. The interpolation model is implemented in a GIS environment and was tested in the Terzona river basin (Italy). Good agreement with field data was obtained during validation and mean soil depth errors are significantly lower than those derived from other topography-based methods. The coupling of the soil depth model with the infinite slope model for shallow landslide stability also provided promising results, confirming that this method can provide a significant contribution to the prediction of shallow landslide hazard, soil losses, sediment production, etc. when utilized in conjunction with distributed hydrological and geomorphological models.